XIII. Electronic Parts Engineering

ENGINEERING MECHANICS DIVISION

A. Radiation Effects on Electronic Parts: Literature Search and Data Evaluation, *K. E. Martin*

1. Introduction

In support of the Thermoelectric Outer-Planet Spacecraft (TOPS) Program, a literature search and data analysis program was contracted with The Boeing Company, Seattle, Washington. The program started in July 1969 and was completed in May 1970. The objective of the program was to establish the basis for the TOPS electronic parts radiation effects support program.

Under the program, the contractor was required to search existing industry and government radiation effects literature and select and analyze pertinent data relating to the TOPS radiation criteria. Based on these findings, JPL will apply the information to anticipated TOPS electronic parts usage and recommend a program for radiation testing support to complement the testing already completed by other agencies. Radiation hardening and screening procedures will also be evaluated and recommended.

2. Discussion

The radiation environments considered were (1) that produced by radioisotope thermoelectric generators (RTGs), i.e., low-level steady-state fission neutron and gamma spectra, and (2) high energy protons, both those generated during solar events and those trapped in planetary belts. Although it was beyond the scope of this program to consider electron effects, where data was readily available, such effects were included. During the course of the program, facilities such as the following were utilized:

(1) Radiation Effects Information Center, Battelle Memorial Institute.

(2) NASA (computerized search performed by the Boeing Aerospace Technical Library).

(3) Defense Documentation Center.

(4) Defense Atomic Support Agency.

(5) Boeing Aerospace Library.

These searches resulted in hundreds of references of which about 260 were retained after reviewing for pertinent radiation environments and part types. Analysis of the literature revealed that, in general, for most part types there are at least some neutron and gamma ray data but that for many types no proton data exists. Primarily, the analysis was directed toward the determination of permanent degradation of parameters, temporary

drifts of parameters, parameter degradation factors, and radiation hardening and screening procedures. The relative sensitivities of components as determined from the analysis are summarized in Figs. 1, 2, and 3. This information is a composite average of test data for many devices within the generic types, and it must be emphasized that specific devices within a given generic type may be far more radiation resistant than indicated in the figures. In many cases, the damage levels were different for the same part types tested at the same radiation levels by different agencies. This in part could be due to such factors as variance between manufacturer's lots, application of different power levels during radiation exposure, and variation in measurement methods and equipment. The vertical dashed lines represent the presently estimated total dose or fluence levels to be experienced by the electronic parts for the TOPS missions. A part type with the bar bisecting or a portion of the bar to the left of this dashed line is considered a problem area and will warrant special consideration. These degradation levels are generally pessimistic as they do not consider radiation screening, radiation hardening, specially selected devices, annealing effects, or circuit compromises, although it does indicate that serious problems exist.

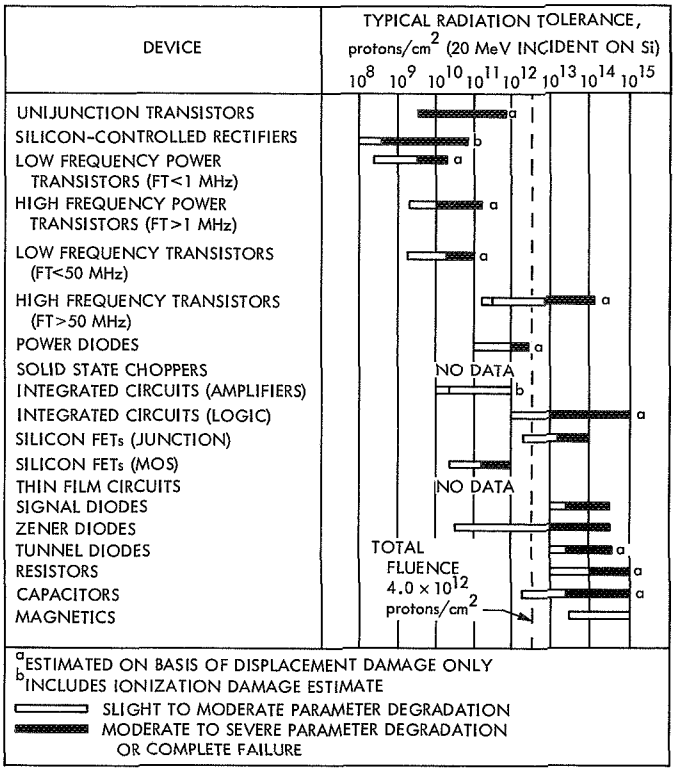

Fig. 2. Survey of component proton degradation

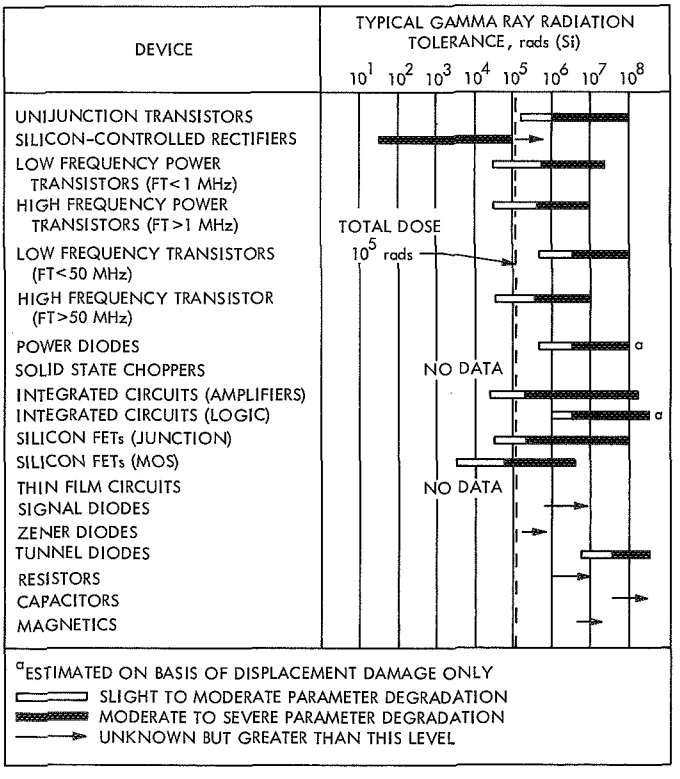

Fig. 1. Survey of component gamma degradation

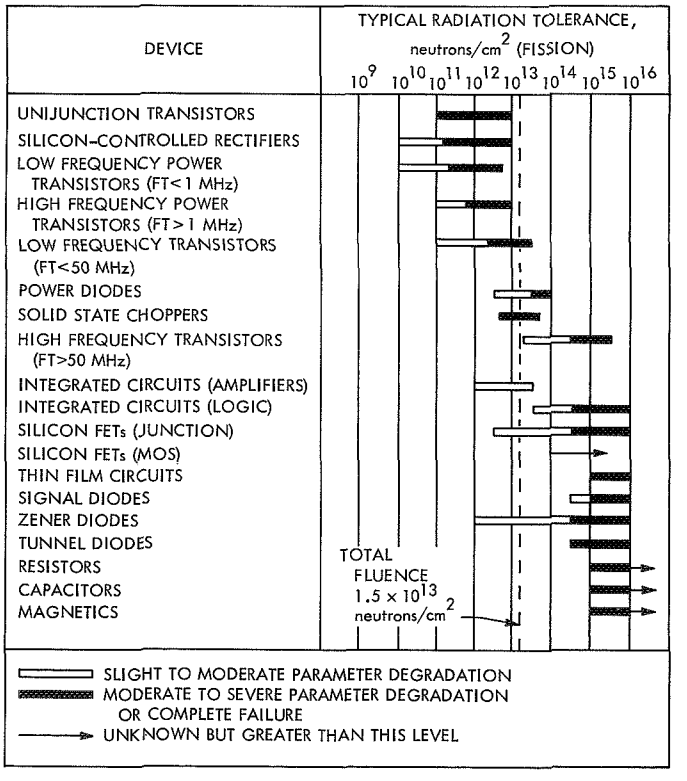

Fig. 3. Survey of component neutron degradation

In general, silicon-controlled rectifiers (SCRs) and unijunction devices appear to be very vulnerable and SCR response is especially unpredictable. For this reason it is recommended that their usage be avoided where possible. Power and low frequency transistors appear to be the next most vulnerable group. Since their behavior is better understood, these devices can be used if sufficient gain margin is allowed or other concern is taken. It should be noted that in some cases shielding may be necessary.

Linear integrated circuits, reference diodes, and metal oxide semiconductor (MOS) devices also present a problem but, if properly characterized, should be usable. In all three cases, in order to assure reliable performance, testing of statistical samples is recommended. Resistors, magnetics, capacitors, and relays, in comparison to the active semiconductor components, do not present a serious degradation problem, although the effect of low-level radiation exposures on long-term reliability has not been fully evaluated.

3. Conclusions

From the review of the preliminary report, it can be concluded that:

(1) With the present estimated TOPS radiation levels, capacitors, relays and switches, resistors, and magnetic devices should not be a problem with the possible exception of the unknown effect of combined neutron, electron, gamma ray, and proton environments.

(2) The available information indicates that many active components will be seriously degraded by radiation during interplanetary missions.

(3) In many cases, data is inadequate to do more than make gross estimates of degradation of part type performance.

(4) Data evaluating proton damage is not available for many part types.

(5) For most part types, hardening and screening procedures are not known or are in a developmental stage.

(6) Although part degradation can be estimated for each environmental component, there is no data indicating how to assess the total degradation due to combined radiation environments.

(7) Using currently available data, system reliability in a radiation environment will be difficult to assess, particularly for part types for which the radiation levels are near the threshold of damage. Even methods of assessing such damage needs to be more fully explored.

It is recommended that:

(1) Evaluation testing be performed to obtain data on part types where no data exists or where lack of data is significant.

(2) Testing with combined radiation environments be performed to obtain insight into how to assess the total threat to parts in interplanetary missions.

(3) Methods of assessing reliability screening and hardening of irradiated components be more fully explored.